





THE ZOOLOGY OF TO-DAY

Opening Lecture for the Session 1918-19, delivered
before the Faculty and Students of
the University of Manitoba,
October 9th, 1918.

DISCARDED

Being the Inaugural Lecture
of
CHARLES H. O'DONOGHUE
Professor of Zoology

UNIVERSITY OF MANITOBA

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PREFACE

In 1918 the University of Manitoba founded the Chair of Zoology, and the following address, delivered as the Opening Address for the Session 1918-19, was also intended to mark this step in the extension of its Science Departments. The University authorities decided that it should be issued in a printed form. It is therefore presented in the following pages, and, apart from a few minor alterations in wording, stands as it was delivered. I am conscious that it is incomplete; what address covering so wide a subject would not be, and the consideration of certain aspects of Zoology were purposely omitted. For example, the advances in classification, in descriptive Morphology and in descriptive as opposed to experimental Embryology, were not dealt with, although I am aware that they are essential to Zoological progress. This was because they would have required a more specialized treatment than was desirable at such a time, and also because it does not appear that we can look for any striking discoveries along these lines in the immediate future. Then, too, it appeared desirable to call attention to certain more or less pressing local requirements, and to research work that has had and will have a direct bearing upon everyday life.

When it was determined to print this address it was also suggested to me that it would be an advantage to indicate where further information on the subjects touched upon could be found, so that it would also act, to a certain extent, as a guide in reading. This has been done by the addition of foot-notes. The works referred to by no means constitute an exhaustive list of the literature, which would, as a matter of fact, occupy several large volumes in itself. It is hoped that the references will give access to much of the recent work that is in language not too technical for the ordinary University reader to follow, and that is available in the University, and the quotations also emphasize the urgent need for the support of research in this country. In certain cases it has been impossible to avoid the mention of purely technical papers.

C.H.O'D.

THE ZOOLOGY OF TODAY

Introduction

I felt highly complimented when I received the invitation to deliver this, the first public lecture of the session, but it was with great trepidation that I accepted it. I have not been with you long enough to be familiar with your traditions, nor to know quite what is expected from the lecturer on such occasions.

It is the custom in certain of the older Universities for a newly appointed professor to deliver an Inaugural Address, open alike to members of the University and the public. Having the fortune to hear two very interesting lectures of this kind I came to the conclusion that the institution was an excellent one, but since undertaking to give this lecture which, I presume in some measure corresponds to them, I have been reconsidering my former judgment.

In such addresses it is customary for the professor to choose some branch of his subject in which he is specially interested, and to deal with it in a broad, philosophic manner, omitting all unnecessary details. This is a very desirable plan, since on the one hand it gives the lecturer great scope for bringing forward interesting matter, and on the other, the audience have an opportunity of hearing well considered judgments from one who is thoroughly versed in his subject.

I have decided on the present occasion not to proceed along these lines for reasons I shall mention later, but to attempt a wider though necessarily shallower review of the present position of Biology and particularly Zoology, the science in which I am myself interested, and its relation to other branches of learning. This must of necessity be incomplete, since it is beyond the power of one man to be abreast of all the manifold ramifications of this subject.

The older seats of learning have their traditions extending back for many decades, and the Professor of Zoology

comes to a department with its own well established traditions. Its past history has made for it a position in the University life that is well known to all, a more or less circumscribed position in the curriculum and relations with other sciences, and the body corporate, which, if they are not accurately defined, are at least more or less clearly understood. In the present instance, however, the case is somewhat different, for in this University so far, Zoology has held the place of Cinderella among her sister sciences. It has only just been raised to the dignity of a fully independent department, of which the Council has paid me the honor to elect me Professor. The future, however, is full of possibilities, and I hope that ere long the department will be worthy of its fellows in the University of this, the greatest city of the West. I am further encouraged to follow this course since my colleague, Professor Buller, adopted a similar plan six years ago, when, with that thoroughness that characterizes all his work, he chose for his theme, in the opening address,¹ "The Progress of Science." In this he indicated the main advances that had been made in all the sciences, and emphasized the need for research. My own review will not cover such an extensive field, but will be in some respects a corollary and an amplification of his, laying special stress on the Zoological aspect.

The starting point of all modern Zoological work goes back to the publication of Charles Darwin's famous book on "The Origin of Species," in 1859.² It is probably no exaggeration to say that this book had a more profound influence on all branches of thought,³ and not simply Biology alone, than any other that has appeared since or for some hundreds of years before, and we are proud

1. Buller, "The Progress of Science, an Opening Address for the University of Manitoba." Published by the University, Jan., 1913.
2. Darwin, "The Origin of Species by Means of Natural Selection, or the Preservation of Favored Races in the Struggle for Life," London, 1859.
3. *vide* "Darwin and Modern Science." A series of 29 articles, each by an author of world-wide eminence. Edited by Seward, Cambridge, 1909.

to think that it was written by a Zoologist. Its publication was followed by a storm of discussion and a great deal of that intellectual friction that tends to generate heat rather than light. This gradually died away, as the main principles it advocated were accepted by all Biologists, and then followed a period of activity in research and revolution in ideas such as had not been witnessed since the great revival of learning, at the end of the 15th and beginning of the 16th centuries. Whether or not all his interpretations of the causes at work were right does not concern us here so much as the inestimable service he rendered in bringing home the great fact of Evolution,⁴ and thereby providing a solid foundation for future endeavor. Zoological and Botanical work, previous to this, had resulted in the accumulation of an enormous number of facts, and large collections of material, but, as Theseus would have been lost in the Cretan labyrinth without the thread supplied by Ariadne, so would the Biologist have been lost in the maze of individual and unrelated observations, but for the clue provided by Darwin.

General

Then followed a period fertile in endeavor, and rich in results, and perhaps mainly concerned with the amplification of the examples of Evolution, the gathering of more facts concerning the structure of animals, and observations on the wonderful way in which the animal is adapted to the life it leads, and is in harmony with its surroundings. Lack of time necessitates that this intervening period¹ should be passed over, and also it is to some measure covered in Professor Buller's address, but three important advances in technique that have contri-

4. *vide* Delage and Goldsmith, "The Theories of Evolution." English edition, London, 1912; and Judd, "The Coming of Evolution," Cambridge, 1910.

1. It includes of the work of such men as Pasteur (*vide* Frankland, "Pasteur," London, 1898); and Metchnikoff (*vide* O'Donoghue, "Obituary Notice of Elias Metchnikoff," Science Progress, 1914), to mention only two.

buted enormously to the results of modern research, and indeed to a large extent conditioned them, call for notice.

1. The first is the improvement of the Microscope,² an instrument with which you are doubtless all familiar. This instrument was brought to a high state of perfection both mechanically and optically, so that now by its means it is possible to view an object magnified about 1,250 times in each direction, *i.e.*, roughly, as if a postage stamp were viewed enlarged to the size of the floor of a hall 100 feet by 75 feet. Further, by means of controlling the color of the light used for illumination, many fresh details of the minute structure of animals can be made out, and permanent photographic records taken of them. Means of taking accurate measurements of the objects under the microscope have also been invented.

2. The second, are great improvements in the methods of dealing with minute objects or parts of larger objects, and rendering them transparent for examination under the microscope. These have been made along three lines. Firstly new methods of fixing the animals, *i.e.*, killing the animals in such a way as to leave their intimate structure as nearly possible like that when alive, have been devised. Secondly, a large number of different coloring matters can be used for staining the preparations, and these, in particular the coal tar dyes, enable us to stain the various constituents of animal tissue in different ways. Lastly, by means of an instrument called the microtome, it is now possible to cut material that has been properly prepared into thin slices or sections $1/1,000$ of a m.m. or less than $1/25,000$ of an inch thick. Indeed, it is a more or less simple matter—after some years of training and practice—to cut a tiny animal into a series of such sections, 2,500 of which together would only measure one inch.

3. The third advance is a method of making models, which reconstruct small animals on an enlarged scale.

2. *vide* Beck, "The Theory of the Microscope." Cantor Lectures, Royal Soc. of Arts, London, 1908; or any modern book on the microscope, of which there are many

from a series of colored transparent sections, such as that described. Images of these sections are projected in turn on to a drawing table by means of special apparatus, much in the same way as the pictures in a magic lantern are thrown on to a sheet, and drawn on thin paper at a known magnification of, let us say, 100 diameters. The paper is rolled with a heated roller on to a wax plate to which it adheres, and which, by means of guides, is made 100 times the thickness of the original section. The plates are then cut out the desired shape by following the lines of the drawing with a sharp knife, and stuck together in their proper order. Thus we have a model of the original animal magnified 100 times in each dimension, and this we can easily examine. Moreover, if we do not want the whole animal we can obtain a model of any internal structure. Not infrequently, as in this example,³ we leave the outside of the animal on one side, while on the other we show some of the internal organs. This method of investigation has the advantage of leaving the original sections uninjured, and so available for other work or for the purposes of reference or checking measurements. Its utilization has taught us a great deal about the structure of minute things, particularly of the early stages of growth, when the embryo or developing animal is too small to be examined accurately by any other means.

A modification of this method has been recently applied to the reconstruction of fossils with satisfactory results, save that in this case, unfortunately, the original material has to be destroyed in the process.

These then are the three mechanical advances which have enabled modern Zoological Science to take such enormous strides along certain paths.

Zoology is a science whose boundaries cannot be accurately laid down. By derivation Zoology (Gr. *Zōon*, an

3. The method of making such models was briefly shown, and the finished model referred to was that of a human embryo about three weeks old, magnified about 50 times. One side of this was left intact, and the other dissected, to show the internal anatomy.

animal, and *λογος*, a discourse), should include all that concerns animals, not excepting man himself, and indeed in its earlier, introductory stages, it does include the foundations of all this enormous field, for the same basic principles apply to all its many branches. In more advanced stages, however, it has been expedient to separate off certain parts of it, owing perhaps to their particular technical requirements, or more frequently to the fact that they are of immense and immediate importance to man himself, or his occupations. Thus it comes about that tradition, convenience, or, it may be in some instances, local exigencies, condition which part of it shall be allocated to the Zoological Department of a University, and which part elsewhere. We find almost always a group of Medical Sciences including Physiology, Human Anatomy and the like; a group including the study of the animals of the soil, Applied Entomology and Genetics, the study of breeding, in close relation with Agriculture and Horticulture; Hydrobiology and Limnology, the studies of the conditions of life in salt and fresh water, bound up with fisheries; and lastly Palaeontology, the study of the fossil remains of animals, intimately connected with, indeed forming an integral part of Geology, and so related to mining. It should be borne in mind, however, that these are all offshoots from the main stem, the same fundamental laws and principles underlie them all, although they are manifested under different conditions and approached by different paths. If you consider what an enormous range of interests this covers, and how the "Pure Zoologist," whatever that may be, can experience the pleasure of trespassing on so many grounds, often considered the preserves of another science, you might expect him to be satisfied, but he is not. We find that the lower plants and animals merge indistinguishably into one another, and there are groups of forms that are treated of in both botanical and zoological text-books, and further, many of the laws of breeding and inheritance are common to animals and plants alike. The zoologist, therefore,

with a rapacity for the acquisition of knowledge that is amazing, breaks into the garden of his sister the botanist, to cull therefrom any flowers or fruits that may serve his ends. And she, on her part, with that interest in fraternal possessions that indicates a well-ordered family, returns the raids.

We may now perhaps, consider briefly some of the lines followed in modern research, and in so doing I shall be able to omit one of the most important, namely Physiology, as my colleague Professor Vincent can speak on this subject far more authoritatively than I.

Palaeontology

We may roughly define Palaeontology¹ as the study of the fossil remains of living beings. Few things could call up a more dreary picture to the uninitiated than such a subject, for, has not the very word fossil, in its colloquial use come to be applied to a person who is as "dry as dust," remote from the world, and presenting no points of interest or sympathy to his fellows. Yet this is a grave mistake, for it is a study full of poignant interest, as its recent advances show. By its means the dead past becomes again clothed with life, old-time animals have slowly yielded their buried secrets to the patient investigator with a two-fold result. In the first place, and from the spectacular point of view, we have a vivid picture² of bizarre and enormous forms, beside which the dragons, centaurs and other weird beasts of our childhood, or of classical mythology, pale into insignificance. These creatures, with their manifold variety and often extraordinary shape, bring home, in a most striking manner, the prodigality of nature, and cause even the most casual observer to pause and think. Secondly, we find, in spite of this vast diversity, that in all cases there is manifested a

1. *vide* Watson, "Palaeontology, its Aims and Methods," Science Progress, 1916.

2. *vide* Hutchinson, "Extinct Monsters and Creatures of Other Days," London, 1910; and also other works quoted under 6.

steady and orderly process of change; sometimes slow, sometimes quick, but always onwards—the progress that we term Evolution. Indeed, palaeontology is the branch of science that provides the actual direct evidence of this phenomenon, and herein lies its great value to the zoologist.

When we wish to know how the elephant got his trunk we no longer turn to the "Just so Stories," but instead, we consult Andrews³ on the Proboscidea, the group of animals in which the elephants are placed, and there find an account which, if less amusing, is certainly more convincing. So it is also with the peculiarities of many other living animals; they are explained when we read their history in the rocks. The outstanding instance of such a past record is that of the Horse,⁴ made classic by Huxley,⁵ but added to and made far more complete since his day, particularly by workers in North America.

Hyracotherium, first of the forerunners of the horse, was found far back in time, it may be two or three million years ago, and the earliest known specimen of this animal so far discovered, was found in the London clay in England. It was about the size of a small fox, standing 11 inches at the shoulder and quite unlike a horse. The fore foot had four toes, with indications of a fifth, and the hind foot three toes, with indications of a fourth. It was fitted for a life in the woods, which then covered the whole of the Northern hemisphere, and probably it wandered through these vast forests, perhaps even from the "Old Country" across Asia, and via a strip of land situated where we now find Bering Strait into Alaska, Canada and the United States, where it was found in a slightly modified form as *Eohippus*. Even the hardy Norsemen, then, cannot claim to be the first European immigrants to this land. Apparently it died out in Eurasia, while in North

3. *vide* Andrews, "Catalogue of the Tertiary Vertebrata of the Fayûm, Egypt," British Mus., London; and Scott quoted under 6.

4. *vide* Matthew, "The Evolution of the Horse," *Amer. Mus. Jour.*, Jan., 1903.

5. Huxley, "Lectures on Evolution, Lecture III., The Demonstrative Evidence of Evolution," New York, 1876.

America it flourished, and underwent a series of changes, becoming modified in structure and increasing in size. From time to time it went back, as it were in an attempt to re-colonize Eurasia, but with poor success. Meanwhile the character of Southern and Central North America was changing from a forest land and becoming transformed into grassy plains, the prairies, and with this change the horse also became modified from a forest animal to a dweller on the plains. Its teeth became suited to the refractory nature of a grass diet, and it had only one toe on each foot, and indeed was much like a modern horse. Now it re-invaded Eurasia with marked success, and spread over the plains there. Some time later the Bering isthmus broke down, and subsequently the horse died out entirely in America. Why it did so is not known, for upon its reintroduction by the Spaniards, it again multiplied and filled the plains.

This is a hurried account of but one of the many histories⁶ that have been made out, piece by piece, and an enormous number of intermediate forms between the dawn horse and its modern descendant have been discovered, and now enrich the Natural History Museum in New York, to whose activities we owe much of this wondrous tale.

It was the custom some years ago to demand "missing links," by which was meant forms intermediate between living groups of animals, and the most clamorous of the doubting critics who demanded them have, by their silence, admitted that even they are satisfied. A number of such forms have been discovered.

Few groups of animals are more readily distinguishable, even by the layman, than the Mammals whose skin bears hairs; the Reptile, whose skin is covered by

6. *vide* Scott, "A History of Land Mammals in the Western Hemisphere," New York, 1913. Osborn, "The Age of Mammals," New York, 1910. Williston, "American Permian Vertebrates," Chicago, 1911. Williston, "Water Reptiles of the Past and Present," Chicago, 1914; and also various popular publications of the American Museum of Natural History.

scales, as in snakes and lizards, or shell, as in the tortoise, or is turned into a hide, as in the alligator; and lastly, the Amphibia, frogs, toads, newts, etc., whose skin is bare, and who possess no claws or nails. Owing to the work, particularly of English palaeontologists like Seely, Broom⁷ and Watson,⁸ on the fossils of the Karroo formations in South Africa, it is now a matter of difficulty, when we take into account the fossil forms, to tell where one group ends and another begins, and doubtless they will all soon be placed in one great association, the Tetrapoda, or four-footed animals.

Of late years the United States has been particularly active in the field of palaeontology, on material gathered, not only from their own country, but from Canada as well. Following the tradition of men like Cope, Leidy and Marsh, and under the leadership of others like Lull, Osborn, Scott and Williston, they have built up a world-famous school, whose work has been crowned with a generous measure of success.

The Canadian Geological Survey, particularly Lambe,⁹ has done some very good work, but why not a Canadian school of palaeontology?

Bionomics

By Bionomics we understand that branch of Zoology that deals with the animal, not as a separate entity, but as part of a life-complex, consisting of many interlocking parts. It treats of the manner in which animals obtain their food, their migrations^a and the way they affect and are affected by the other animals, the plants and the in-

7. Broom, "A Review of Recent Advances in South African Vertebrate Palaeontology," *Amer. Jour. Sci.*, Vol. xxxv., 1913. Broom, "South African Fossil Reptiles," *Amer. Mus. Jour.*, Vol. xiii., 1913. Broom, "Croonian Lecture; On the Origin of Mammals," *Phil. Trans. Roy. Soc., B.* 1914.

8. *vide* also various papers by Watson in *Mem. and Proc. Manchester Lit. and Phil. Soc.*, 1908-12; and *Proc. Zool. Soc.*, 1914 *et seq.*

9. *vide* papers by Lambe in "The Ottawa Naturalist," and in the publications of the Geological Survey of Canada.

(a) *vide* Meek, "The Migrations of Fish," London, 1916; also Clarke, "Studies in Bird Migration," London, 1913.

organic world with which they are brought into contact. It is a comparatively young study, but its possibilities are great, and it is of course intimately bound up with Botany. To a certain extent it is a return to the once despised "Natural History,"¹ but it applies more exact methods than were formerly used. In England there is a journal² devoted to it, more especially its botanical side, in which, for example, recent papers by Farrow³ have shown what a large part such an animal as the rabbit plays in determining the character of the plants that live on a given area. The great change that swept over the animals and plants of the island of St. Helena, owing to the introduction of goats, is another much quoted and well known instance. On this continent a good deal of valuable research has been carried out, and although some of it relates to the land,⁴ most of it is concerned with the life conditions of our unequalled water systems.⁵ It is not obvious why the outbreak of a disease in rabbits, caused by parasitic worms, should have any effect on the yield of all sorts of fur in the country. Yet this is actually the case, as has been shown by Hewitt.⁶

Turning now to the waters, we find that they are teeming with small floating organisms,⁷ some of microscopic size, and some just visible to the naked eye. These, insignificant as they appear at first sight, are nevertheless of great importance, since directly or indirectly, they provide food for all the fish. Here we are dealing with a subject still in its infancy, but which not only has con-

1. *vide* for example Roosevelt, "African Game Animals," London, 1915.
2. *The Journal of Ecology*, Cambridge, 1912, *et seq.*
3. *vide* Farrow, "On the Ecology of the Vegetation of Breckland," *Jour. of Ecol.*, 1914, *et seq.*
4. *vide* Shelford, "Animal Communities in Temperate North America," Chicago, 1913.
5. *vide* Needham and Lloyd, "The Life of Inland Waters," New York, 1916; and Ward and Whipple, "Fresh Water Biology," New York, 1918.
6. *vide* a paper by Hewitt, in publication by the Royal Society of Canada.
7. *vide inter alia*, Kofoid, "The Plankton of the Illinois River," *Bull. State Lab. Nat. Hist.*, Ill., 1908.

siderable economic value, but also opens a field for plenty of very interesting work.

In this Province, with its large lakes and many rivers,⁸ yielding an enormous amount of food, and providing employment for a large number of persons, work is urgently needed.⁹ No bionomic survey has, so far as I can ascertain, ever been attempted; nothing has been done in the matter of a proper scientific enquiry into the best methods of keeping its waters stocked with fish. It is a problem that will soon need serious attention, if fishing proceeds at its present rate. The Dominion Government have indeed got two well-equipped hatcheries on Lake Winnipeg,¹⁰ but their work needs supplementing by local research, and it is to be hoped that such will be forthcoming before it is too late

Parasitology

Parasites, *i.e.*, animals that live on and at the expense of other animals, have received a great deal of attention in recent years, and naturally those affecting human beings call for our first consideration. Many advances have been made, and the enormous benefits resulting from them are only too apt to be forgotten or overlooked in the general race for dollars. It is not possible here to do more than take one or two instances, but luckily much of the

8. Taking the estimate of the "Manitoba Fisheries Commission," 1910-1911, that the water area of the Province is one-fifth of the total area, which is 249,000 square miles, we have a total water area of about 49,000 square miles. This is sufficiently large if properly stocked and controlled to yield all the fish that can ever be consumed in the Province, and a great deal for export for an indefinite period.
9. According to the Annual Report of the Fisheries Branch, Department of Naval Service, for 1916-17, the total yield of fish for the Province during the period covered by the report was 14,387 tons (of 2,000 lbs.), valued at \$1,390,002. The number of men directly engaged in the fisheries was 2,049, and they employed boats, appliances and building to the value of \$407,934. Thus it will be seen that it is an industry of considerable importance to the Province.
10. In addition to the two hatcheries on Lake Winnipeg, there is also one on Lake Winnipegosis, and in the period covered by the report, 267,500,000 fry of various species of fish were hatched and distributed in the two lakes.

work is now available in text-book form¹. Parasites belong in the main to three great groups: Protozoa, tiny forms needing the microscope to see, and its very highest powers to investigate; Worms; and Insects, and their near relatives the mites.

The British Government, in 1809, sent out the ill-fated Walcheren Expedition, consisting of 39,000 men, and in less than four months 4,175 had died, and 26,846 had been treated in the hospitals for a disease we now term Malaria.² The army was withdrawn, defeated, although only 217 had actually been killed by the enemy. That a similar fate has not overtaken our present expeditionary forces in tropical countries is entirely due to the discoveries of recent years. In 1882 it was found by Laveran that this disease was caused by a minute parasite in the blood cells, and later Sir Patrick Manson suggested that these parasites passed part of their life in a mosquito. The disease was then investigated at Bangalore in India by Sir Ronald Ross, who expressed his feelings in lines that conclude thus:

"In this, O Nature, yield, I pray to me.

I pace and pace, and think and think, and take
The fever'd hands, and note down all I see,
That some dim, distant light may haply break.

The painful faces ask, can we not cure?

We answer, 'No, not yet; we seek the laws.'

O God, reveal thro' all this thing obscure

The unseen, small, but million-murdering cause."

In 1898 he was able to lay before the world the history of this parasite, which must spend part of its life in a mosquito, by whose agency it is again transferred to man. Ross³ then proceeded to demonstrate what could be done in the way of controlling the disease, and in 1902 set to

1. Chandler, "Animal Parasites and Human Disease," New York, 1918;
Fantham, Stevens and Theobald, "The Animal Parasites of Man," London, 1916.
2. *vide* Laveran, "Traité de Paludisme," Paris, 1898.
3. *vide* Ross, "The Prevention of Malaria," London, 1910.

work at Ismalia in the Suez Canal, where in a population of 10,000, 1,100 to 2,500 cases occurred annually. After four years not a single new case was reported. When we consider that the deaths from this disease alone in India amount to over 1,000,000 annually, that in the United States in 1907, it was the cause of 12,000 deaths, and according to Howard⁴ the annual financial loss due to this disease is not less than \$110,000,000, it will be seen that it is almost impossible to overrate its importance. The working out of the complex life history of the malaria parasite may justly be regarded as one of the medical-biological triumphs of the nineteenth century.

It led to the investigation of a number of other diseases, for example in 1900 the United States appointed a commission to discover the cause of yellow fever.⁵ The organism responsible for the disease was not discovered, it is presumably too small to see even with a microscope, but it was found that it was carried by a mosquito in the same manner as Malaria. At one time no city on the whole Atlantic and Gulf coasts was exempt from outbreaks of yellow fever, but since 1905, when proper precautionary measures had been taken, no epidemic has occurred in any of them.

Similar results have been obtained in the case of other diseases of both man and cattle. In all these instances a biological determination of the cause and method of dissemination of the diseases preceded their control.

The masterly genius of Ferdinand de Lesseps conceived the idea of a Panama Canal, but he was unable to carry out his plans. In his attempt 16,000 men lost their lives, sacrificed to malaria and yellow fever. The conquest of these diseases enabled the Americans to carry out this project which, but for the biological discoveries I have just mentioned, would have been impossible.

4. Howard, *vide* Chandler (quoted in 1), p. 348; also Howard, Dyar and Knab, "The Mosquitoes of North and Central America and the West Indies," Washington, 1913-17.

5. *vide* Boyce, "Yellow Fever and its Prevention," London, 1911.

The majority of the parasitic worms cause diseases of a most distressing nature, and it is satisfying to think that during the past ten or fifteen years an enormous amount has been done; although here, as elsewhere, more research is needed before all or even most of them can be satisfactorily dealt with. One parasite is of particular interest on this continent, and that is the hook-worm. The children of our neighbours "across the line" often had held up to them as horrible examples the "poor whites," or the "lazy niggers" of the Southern States. Yet this poverty of physical and mental endeavor, this very laziness, for which they were held to scorn, was in almost all cases due to the fact that they were suffering from the results of hook-worm. As soon as this was known a United States commission⁶ set to work, and in the years from 1909-14 treated, more or less successfully, 700,000 sufferers.

The insect parasites of man, save in so far as they are also disease carriers, are not so formidable under the ordinary conditions of life, but on the battlefield and in the trenches they undoubtedly constitute not the least of the "minor horrors of war."

Entomology

The study of insects is one of the best founded of the branches of Zoology, as the beauty of these delightful creatures has always attracted attention, and they have been collected and studied for many years. Although it is only recently that their economic importance has been appreciated, rapid advances have been made which owe a great deal to the wealth of detail amassed previously. Even to the older workers we owe some practical hints. To Reamur,¹ the great French observer, is due the suggestion that it would be possible to make paper from wood

6. *vide* The publications of the Rockefeller San. Comm. for Eradication of Hookworm Disease, Washington.

7. *vide* Shipley, "The Minor Horrors of War," London, 1915. Shipley, "More Minor Horrors," London, 1917.

1. Réamur, "Memoirs pour servir à l'histoire et à l'anatomie des Insectes," Paris, 1734-42.

pulp in the same way as the wasp has done from time immemorial, and every one knows what an enormous industry this is today, and what a far-reaching effect it has had on the press and printing. Fabre,² the most recent of the succession of French students of insects, who has but lately passed from his labors, advised the use of paper bags to exclude moth from clothes and woollens, and to prevent the contamination of food by flies. Yet how many of us using these devices call to mind the poet peasant of Provence?

Over the whole world it is now realized that the damage caused by insects to crops of all sorts is a very serious problem, and energetic measures are being taken to get the matter under control. In this country we have the work of Hewitt, Cameron and other entomologists in the Department of Agriculture,³ but it should certainly be supplemented by investigations carried on in every University in the Dominion. It is not yet sufficiently widely known what an urgent and important matter this really is. For example, it was estimated by the United States Government⁴ that the direct loss of crops due to insect attacks in one year recently amounted to \$1,000,000,000.

Some years ago a fruit grower in California imported a new lemon tree, with which he hoped to improve his own stock, but unfortunately it brought with it a parasite known as the Cottony Cushion Scale, and in a few years, when this got fairly widespread, the orange shipments dropped from 8,000 carloads a year to 600, and the entire industry was threatened with extinction. Spraying and other precautions proved of no avail, but luckily it was discovered that the natural enemy of the scale was a ladybird found in Australia, rejoicing in the scientific name of *Vedalia cardinalis*, and the Secretary of State secured a few eggs. As quickly as possible the insects

2. Fabre, "Souvenirs Entomologique," Paris.

3. *vide* Bulletins and Entomological Circulars, Dept. of Agriculture. Ottawa.

4. *vide* The publications of the Department of Agriculture, Washington.

were bred and liberated, and in a short space of time the scale was suppressed.⁵

Almost identical is the history of a subsequent pest, the black scale,⁶ which, however, was found to be controlled by another ladybird, this time from South Africa. So we might go on, with a whole list, the codlin worm in apples, killed by a small black fly; the brown scale on apricots, attacked by a brown fly, etc., but I hope sufficient has been said to show that research on these lines is a matter of practical importance.

I may appear to have laid too much stress on the monetary aspect of things. This is not because I have overlooked Ruskin's dictum that "There is no wealth but life," but because I have used money as a rough measure of human energy and endeavour that can easily be appreciated. When I say there is a loss of so many dollars, what is really present in my mind is the wastage of human labor that this represents, or the destruction of products otherwise available for man, and it is in this sense that I wish you to understand it.

Heredity

So far I have concerned myself mainly with the facts of Zoology, and have endeavored to indicate the lines of enquiry that recent discoveries have opened up, but it must not be imagined from this that the period has not also produced theories good, bad and indifferent. Nothing would be further from the truth for the reverse is the case, and few periods have been richer in the invention of theories and interpretations of recorded facts,¹ and we

5. *vide* The publications of the California Horticultural Commission.

6. *vide* Harwood, "The New Earth," New York, 1906.

1. In this subject it is impossible to do more than indicate some of the most recent books, but as they nearly all contain good bibliographies, reading in any subject can be pursued further by using the lists therein provided. Doncaster, "Heredity in the Light of Recent Research," Cambridge, 1911. Lock, "Variation, Heredity and Evolution," London, 1916. Minot, "Modern Problems of Biology," Philadelphia, 1913. Morgan, "A Critique of the Theory of Evolution," Princeton, 1916. Osborn, "The Origin and Evolution of Life," New York, 1918. Russell, "Form and Function," London, 1916. Thompson, "Growth and Form," Cambridge, 1917. Thomson, "Heredity," London, 1908.

may say with as much truth as ever "Quot homines tot sententiae; suus cuique mos." I have left them alone, although they are absolutely essential to progress, because in many cases they would have led me into the fields of controversy, and would have made still further demands on your fortitude and patience. Now, however, I have come to certain matters in which it is harder to separate fact from theory.

After the stimulus supplied by Darwin, many biologists, for in this field botanist and zoologist can hardly be separated, started to enquire into the laws governing the wonderful phenomenon of the reproduction of life, and particularly the nature and working of the laws of inheritance and of sex.² In the main they followed three different lines; one set, by utilizing the refinement of modern microscopic technique, turned their attention to the actual structure of the male and female germ cells, from the union of which all higher animals and plants spring; another dealt with the matter experimentally, by means of breeding animals and plants and noting the results; and the third collected large numbers of measurements of different generations of living beings, man included, and analysed them mathematically.

Cytology

You will know, of course, that the body is composed of a vast number of tiny, living units, termed cells, as a brick building is made up of bricks. These are of different shapes and sizes, but one fundamental type of structure underlies them all, each is made of a certain amount of living matter surrounding a denser mass, the nucleus, which is the controlling centre of the cell's activities. Within the nucleus, at certain periods, appear a number of minute rod-shaped bodies, the chromosomes. These are so striking that they have attracted much attention, especially in the germ cells, and they have been found to contain the material responsible for the subse-

2. *vide* Doncaster, "The Determination of Sex," Cambridge, 1914.

quent development of various hereditary characters, e.g., colour of a flower, height, color of eye and so on. Recent work, particularly in the United States has achieved remarkable success and Morgan¹ and his co-workers have been able in the case of a fly, *Drosophila*, not only to show that certain character producers reside in certain chromosomes, but also the approximate position of each within the chromosome. When we consider that the length of one chromosome is only 1/1,000 of an inch, it will be appreciated what a fine accomplishment this is.

Other studies have also been carried out in other aspects of the minute structure of the germ cells, the relation of the chromosomes to sex,² the organization and part played in the development of the animal by the constituents of the cell outside the nucleus,³ the mode of derivation of the germ cells⁴ and so on. Lack of time forbids my doing more than just mentioning these points.

Experimental Zoology

Under this term we include a number of different lines of research, the majority of which are concerned with problems relating to reproduction, development and inheritance.¹ Here also we have a comparatively new line of enquiry that has resulted in numerous additions to our knowledge, but covering far too wide a field to be dealt with adequately now. It is well known that before it can undergo development the female germ cell or egg almost invariably requires to be fertilized by the male germ

1. *vide* Morgan, Sturtevant, Muller and Bridges, "The Mechanism of Mendelian Heredity," London, 1915.
2. *vide* Doncaster, quoted above in 2. Stevens, "Studies in Spermatogenesis, with especial reference to the Accessory Chromosome," Carnegie Inst., Washington, 1905. Stevens, "Studies in Spermatogenesis, Pt. II., A Comparative Study of the Heterochromosomes in Certain Species of Coleoptera, Hemiptera and Lepidoptera, with especial reference to Sex Determination," *Ibid.*, 1906.
3. *vide* Gatenby, "The Cytoplasmic Inclusions of the Germ-cells, Pt. I. Lepidoptera, Pt. II. *Helix aspersa*," *Quart. Jour. Micro. Sci.*, 1917.
4. *vide* Hegner, "The Germ-cell Cycle in Animals," New York, 1914.
1. *vide* Morgan, "Experimental Zoology," New York, 1917; and also numerous papers in the *Journal of Experimental Zoology*.

cell. Now, some years ago it was shown by Loeb² that it is possible in the case of certain of the animals termed sea urchins, to bring about fertilization by purely chemical and physical means, and by further treatment to get the egg cell to go on developing. By means of this and subsequent experiments we have arrived at a much clearer idea of the nature and extent of the forces at work in the early stages of growth. Then, too, much has been done in the investigation of animal behaviour,³ both in the lowest and in the higher animals, and this study of Comparative Psychology, for that is what it amounts to, from a purely zoological point of view, is one of the most interesting lines of modern research. Such questions for example, as to whether an animal learns more quickly by punishment for failure, or reward for success, or by a combination of the two, cannot fail to be of import to all concerned in education.

The aim of this branch of enquiry, as of all experimental sciences, is to thoroughly investigate natural phenomena under known and adjustable conditions so that in the end we may be able to control them as far as is possible.

Genetics

By Genetics we understand the investigation of the problems of inheritance and the determination, by means of breeding animals and plants, of the influence which the parents exert on the characteristics of their offspring.¹ It is really a branch of experimental biology, but, since its methods are somewhat different from those employed in other fields, it is usually considered separately. The

2. *vide* Loeb, "The Dynamics of Living Matter," New York, 1906.

3. *vide* Jennings, "Behaviour of the Lower Organisms," New York, 1915.
Smith, "The Investigation of Mind in Animals," Cambridge, 1915.
Watson, "Behaviour, an Introduction to Comparative Psychology," New York, 1914.

1. *vide* Bateson, "Methods and Scope of Genetics," Cambridge, 1908, p. 34, "Genetic inquiry aims at providing knowledge that may bring, and I think will bring, certainty into a region of human affairs and concepts which might have been supposed reserved for ages to be the domain of the visionary."

breeding-pen is to genetics what the test-tube is to chemistry. The subject received its modern impulse from the simultaneous rediscovery, by three prominent biologists in 1900,² of a paper written by Mendel in 1866.³ In this are recorded experiments made with different varieties of the edible pea and certain principles of inheritance that he deduced from them. A great deal of experimentation has since been carried out on all sorts of living beings, with the result that further laws have been discovered, and we now have a far better idea of what is involved in inheritance than was possible 15 or even 10 years ago. The application of these principles to the practice of breeding has produced some noteworthy results,⁴ some of which have been of great economic value, more particularly in the case of plants. Much has been done in the matter of studying the inheritance of coat colour in cattle, the quantity and quality of wool in sheep, and such characters as trotting or pacing in horses.

Let us take by way of illustration a few small points relating to man himself. We now know why it is that a man and a woman with a particular colour of eye, which we may call "pure blue," or better simplex blue, cannot have children with eyes of any other colour. On the other hand a man with brown eyes and a woman with blue eyes can have children with different coloured eyes.

Two diseases have attracted attention for many years, namely, Haemophilia, in which the patient bleeds profusely from the smallest wound or cut, while a larger one proves fatal, as the bleeding cannot be stopped, and Night blind-

2. The three papers referred to are the following: Correns, "Mendel's Regel über das Verhalten der Nachkommenschaft der Rassenbastarde," Ber. Deutsch Bot. Gesell., xvii., 1900. Tschermak, "Über künstliche Kreuzung bei *Pisum sativum*," Zts. f. d. landw. Versuch. in Osterr., 1900. de Vries, "Sur la loi de disjonction des hybrides." Comptes Rend. cxxx., 1900.
3. *vide* Bateson, "Mendel's Principles of Heredity," Cambridge, 1906. This not only contains an exposition of various Mendelian phenomena, but also a translation of Mendel's papers.
4. *vide* Castle, "Genetics and Eugenics," Harvard Univ. Press, 1916. *The Journal of Genetics*, Cambridge.

ness, where the sufferers are apparently able to see quite well in the daytime, but in the dusk of the evening when the light falls below a certain intensity, they become blind. Supposing a man with either disease marries a normal woman, the children are all apparently normal. If the sons marry, then all their children are normal, whereas in the case of the daughters it is different. Some of the daughters will have normal children, while the sons only of the others will be diseased. That is to say the disease only shows itself in the men, but it can only be carried by the women. This is a striking, and to the lay mind mysterious condition, but is capable of a simple explanation, when the laws of inheritance are understood. The mode of transmission of a large number of other defects are also known, and the result of a marriage with defective stock can be predicted.

Biometry

The special province of Biometry is to collect accurate measurements of various parts or qualities of plants and animals, especially man, and to submit them to mathematical analysis.¹ This is a line of enquiry practically founded by Sir Francis Galton, and continued with striking success by Professor Karl Pearson, to whom it owes its name, in the Biometric Laboratory of the University of London. A large number of measurements and observations have been made on various attributes of man, for example, stature, weight, span, shape of head, type of face, general mental ability, musical ability, congenital deafness, and longevity, etc.² The results show that these characters are inherited in the same manner as are size, length of limb and so on in animals, and the popular adage "Like father like son" is

1. The preliminary work in this field has necessitated the elaboration of mathematical methods for attacking the particular classes of problems presented by the measurement of biological material. *vide* various papers by Pearson, in the Philosophical Trans. of the Royal Soc., and also Pearson, "Tables for Statisticians and Biometricians," Cambridge, 1914
2. *vide* The articles in Biometrika, and also the publications of the Biometric Laboratory of the University of London.

not an empty phrase, but one with a sound biological foundation. This has come out quite clearly from the investigation of the position in the class lists of the University of Oxford of 2,500 pairs of fathers and sons.³ Still closer is the relationship in position in class lists between 4,200 pairs of brothers. This, after all, is what might be expected, because in this case both father and mother were the same. The position in the class list we must regard as at least an approximate measure of the mental ability and application of the student, or our whole system of examinations for awarding degrees is a worthless waste of time. So that we see from these investigations that mental qualities are inherited in a similar way to physical qualities, and other enquiries show that the same is true also of feeble-mindedness, insanity, liability to certain diseases, such as consumption and so on.

Eugenics

Eugenics is defined by its founder, Sir Francis Galton, as "the study of agencies under social control, that may improve or impair the racial qualities of future generations, either physically or mentally." It endeavors to take the results obtained by Genetics and Biometry, and discover in what way they can be applied to man.¹ Obviously man cannot be dealt with in the same way as animals or plants, but nevertheless he is subject to the same laws of inheritance.² This is clearly shown when we collect family histories and examine them in the light of what we already know occurs in animals. It has just been pointed out, too, that the mental qualities of man also behave in the same way. It is impossible to escape from the moral of these discoveries, they must be con-

3. *vide* Castle, quoted above under Genetics 4, p. 247.

1. *vide* Pearson, "The Scope and Importance to the State of the Science of National Eugenics," London, 1909.

2. *vide* Reid, "The Principles of Heredity," London, 1906. Saleeby, "The Progress of Eugenics," London, 1914. Castle, Coulter, Davenport and Tower, quoted under 1 in Heredity.

sidered, seriously considered,³ by the men who make our laws. How rare is it to find in the ranks of the politicians, one who has even the remotest knowledge of these things, and yet they would in most cases unhesitatingly enact laws relating to such matters that might profoundly influence the future of the country they profess to serve.

Certain courses of action, either of the individual or the community, are known to be beneficial, and others extremely detrimental, to the future well-being of a race, and the nation that first realizes this and acts upon it will have an enormous advantage in years to come. Some of the evils may be dealt with by legislation, but many cannot, and most of the desirable ends can only be obtained through the sentiment and conscientiousness of the people individually. The people need to be educated to see that race efficiency and happiness are intimately bound up, and in order to do this a special society was founded some years ago in Great Britain. In addition to this there is also an International Eugenics Congress, a Laboratory of Eugenics,⁴ in the University of London, under Karl Pearson, and a Eugenics Record Office in New York, under Dr. Davenport.

The present world conflict is taking a terrible toll of our finest men. We are losing the best men physically, the best mentally, and those in whom the ideals of justice and liberty were so well developed that they unhesitatingly sacrificed themselves for the future good of the world. This is a spirit that must never die. The present generation must see to it that the succeeding generations are sound in mind and sound in body, in the widest meaning

3. *vide* Pearson, quoted under 1 above p. 45. "On the one hand I do not raise an alarmist picture of our coming decadence, nor on the other would I leave you without insisting that there is grave occasion for earnest thought. I would raise interest in a new and, I believe, potent branch of science; I would call for a strengthening of racial conscience, and a scientific basis for conduct, as our growing civilization stems natural selection as the natural purifier of the State. Thus it is that Eugenics passes from Science into practice, from knowledge into a creed of action."

4. *vide* The interesting series of publications of the Galton Laboratory for National Eugenics, University of London.

of both phrases, and this can only be done when the people as a whole realize the biological forces that are at work, and see that they are well and truly applied.

Research

I trust I have said enough to convince you of the extreme importance of Zoology in many branches of life. It is required as an integral part of the training of the Medical man, the Agriculturist, the Horticulturist, the Geologist, and any one who is connected with the conservation of our natural resources or the governing of the country. Since it deals with the ordinary phenomena and the laws governing the lives of animals, in which we must include ourselves, it should also find a place in any curriculum that aims at a properly balanced education in the highest and best sense. If I have failed to bring home to you that it also is a subject of fascinating interest, the fault lies with my inadequate presentation, and not with Zoology itself.

Before bringing these remarks to a close I should like, if you will grant me your indulgence, to touch on one other matter that is a vital necessity to Zoology as to all other sciences, namely, Research. The great achievements of the past, the results of a vast amount of laborious research, are now available to each and all of us, and it behoves us not simply to utilize them to their full, and let them drop, but to carry them further to the best of our abilities "Et quasi cursores, vitae lampada tradunt."

Many of the blunders in the early stages of the war were due to an appalling lack of scientific knowledge, and a lack of that ability to attack new problems that is engendered by research alone. This called for protests on the part of all the leading scientific men of Great Britain.¹ Indeed, so imperative was the need, that

1. *vide* A letter in *The Times* of the 2nd February, 1916, signed by 36 of the leading scientific men in Great Britain; and "The Report of a Conference on the Neglect of Science," held in London on the 3rd May, 1916.

It is interesting to recall in this connection the remark of Pasteur in a letter to his old pupil Raulin, soon after Sedan:

throughout the Empire committees were established to organize and assist the prosecution of "Scientific and Industrial Research." The committee in this country² has already done much useful work, and has appealed to the Universities for co-operation.³ I feel that I must emphasize the point here for, in the short time I have been among you, I have encountered an indifference to research, not only outside, but to a certain extent inside, the University, that is strangely out of keeping with the part such work must play⁴ in the future of this Dominion, and of the Empire of which it forms a part.

The great educational value of research is that it causes the student to think for himself, which is, after all, what he

"But, as you say, if we rise again from these disasters, we shall again see our statesmen lose themselves in endless discussions on forms of government and abstract political questions, instead of going to the root of the matter. We are paying the penalty of fifty years forgetfulness of science, of its conditions of development, its immense influence on the destiny of a great people, and of all that might have assisted the diffusion of light."

2. *vide* The "Report of the Administrative Chairman of the Honorary Advisory Council for Scientific and Industrial Research of Canada," Ottawa, 1918. P. 24: "Science in Canada has, therefore, not come into all her own in the academic world. The work of the eighteen Universities is still in the main along lines outside science. Their departments of Science, pure and applied, are of comparatively recent origin, and the majority of them, it must be said, are very inadequately maintained."
3. *vide* Adams, "The Need for Scientific Research," Ottawa, 1918. P. 7: "If Canada is to maintain and improve its position among the countries of the world, it must do so by learning how to work up its abundant raw materials into the cheapest and best merchantable products by the application of scientific knowledge to this work in hand. More extended facilities for research and a greater number of highly trained men are needed now in preparation for the forward movement which Canada must make on the resumption of peace, if she is to retain her place among the nations of the world. And above all, the people of Canada must awake to the necessity of action in the matter of industrial research, and recognize that if millions of dollars are being expended by governments and by individual companies in other countries for the development of industrial research, Canada cannot hope to achieve results unless she is willing to meet the necessary outlay."
4. *vide* Fields, "Science and Industry," Ottawa, 1918. P. 2: "What excuse can we Canadians offer in extenuation of the fact that the leading Universities of the United States have left our Universities far behind in the matter of research? If the people of Canada realized the significance of the modern scientific

has to do when he faces the world. Learning alone tends to make him rely on tradition and authority, and consequently he feels lost in the face of new problems. Research is therefore the natural corollary and corrective of learning, and is the true finish of any University career.

There is a marked break in our intellectual lives. We start by being taught, and we end by learning for ourselves; we cease to be the passive recipient and become the active agent. It is this break that comes to the boy leaving his school and going out into the world. Now in the case of his proceeding to a University only too often this break does not occur, and he continues a scholar instead of a learner, although he should have ceased to be a child and become a student. Here is the profound mistake. The University is *not*, or should not be a school; the professor is not a teacher in the same meaning of the word as used in connection with a school. The University is an entrance to the mine of knowledge, its libraries, its laboratories and its museums, the tools wherewith the student can delve for its treasures. And what of the professors? Are they just improved automatic text-books that walk about of themselves, and pour out information as from a gramophone, in order that the student may be saved the trouble of reading for himself? I venture to say they are not, although they are only too frequently considered so, partly of course from the traditions of the Universities of the Middle Ages, when the professor's lectures were the only text-book available, and partly also because the functions of a University are not properly understood. The University is a seat of *learning*, not a seat of *teaching*; the great distinction marking it off from a school is its research or its power of fostering the research spirit, and consequently the presence

movement, they would see to it that the necessary funds were forthcoming, and they would surely insist, as a matter of national pride, on our Universities taking their place alongside the foremost in the world. This would mean on the one hand more time, and in some cases better equipment, at the disposal of the members of the staff, in order that they might be scientifically more productive."

of research students is essential to the healthy life of any department. The professor is naturally, to a certain extent a book of reference for facts, but still more should he be "a guide, philosopher and friend." He has toiled longer in the mine, he has fallen where the student will fall, but has gone on, and by his failures made the path easier to follow. But this, the ideal position for the professor, can only be maintained if the student on his part is keen to break ground for himself,⁵ to strike out on a new trail, that shall carry him into the great unknown. Here he will encounter obstacles that have to be removed or circumvented, but they will only stir him to further efforts, for even the arch-pessimist Schopenhauer was forced to admit that "to overcome difficulties is to experience the full delight of existence."

It is impossible to estimate the value of research to the future well-being of the community,⁶ and difficult to exaggerate its influence upon the mind of the individual engaged in it. It keeps him alert, keen and enthusiastic, ever ready to receive and to act upon new ideas, and he too can experience those precious moments that are granted to the mountaineer and the explorer. The research worker who has brought a piece of investigation to a finish, and has seen new vistas opened by his patient toil can also say:

"—Then felt I like some watcher of the skies
When a new planet swims into his ken;
Or like stout Cortez—when with eagle eyes
He stared at the Pacific, and with all his men
Look'd at each other with a wild surmise—
Silent, upon a peak in Darien."

5. *vide* Miers "Oration Entitled The Revival of Learning," Univ. Coll., London, 1909, in which the attitude of the student to research is discussed.

6. *vide* The examples given in Harwood, "The New Earth," New York, 1906; also in Fields quoted above under 4, and particularly Gregory "Discovery the Spirit and Service of Science," London, 1916, in which this aspect of research is most fully and sympathetically dealt with.

